

## SUBSTITUTE SPECIFICATION MARKED UP

METHOD AND APPARATUS  
FOR AUTOMATIC APPLICATION AND  
MONITORING OF A STRUCTURE TO BE  
APPLIED ONTO A SUBSTRATE

[0002][0001] The present application relates to and claims priority from European Application Serial No. PCT/EP2004/007964 filed July 16, 2004, titled “METHOD FOR AUTOMATIC APPLICATION AND MONITORING OF A STRUCTURE TO BE ADPLIED ONTO A SUBSTRATE, AND DEVICE THEREFORE”, the complete subject matter of which is hereby expressly incorporated in its entirety.

[0002] The present invention relates to a method for automatic application and monitoring of a structure to be applied onto a substrate, and a corresponding apparatus therefore.

[0003] For automatic application and monitoring of a structure to be applied onto a substrate, it has been customary to carry out optical measurements, whereby. For automatic application and monitoring of a structure, frequently various systems for fully automatic testing of the structure, including adhesive and sealing agent lines, are used for this purpose. For this purpose, multiple video cameras are directed at the structure to be recognized, whereby, in addition, an illumination module serving to generate a contrast-rich camera image is required.

[0004] In order to be able to monitor an adhesive line and/or adhesive trail while it is being applied, it is necessary to teach-in a reference adhesive trail, (i.e., to have the camera or cameras scan the reference adhesive trail,) in order to calculate therefrom corresponding parameters on which the assessment of the applied adhesive trails is based subsequently based.

[0005] However, individual components are not always supplied to the same position of the application facility and/or the apparatus for automatic application and monitoring by means of the supply supplier of the technology. Moreover, application of an adhesive trail to a fold or joining seam requires correction of the tolerances of the

## SUBSTITUTE SPECIFICATION MARKED UP

individual components and/or correction of the position of the individual joining seams and/or folds.

[0006] Moreover, there is a need for a method for automatic application and monitoring of a structure to be applied onto a substrate, preferably an adhesive agent trail and/or an adhesive trail, whereby. In addition, the application structure and/or adhesive trail is monitored at a high accuracy while it is being applied.

[0007] It is therefore the object of the present invention to provide a method for automatic application and monitoring of a structure to be applied onto a substrate; whereby the. The application structure and/or adhesive trail is monitored at a high accuracy while it is being applied, and whereby automatic. Automatic control of the application facility and/or positional correction-- with regard to positional tolerances of the individual components and/or tolerances of the joining seams or similar structures-- is facilitated.

[0008] Moreover, it is an object of the present invention to provide a suitable apparatus for carrying out the method according to the invention.

[0010] ~~These objects are met with regard to the method by the features of claims 1 and with regard to the apparatus by the features of claim 15.~~

[0009] According to the invention, a method for automatic application and monitoring of an adhesive trail onto a substrate and/or component, in particular a fold or joining seam, is proposed, whereby. A reference edge or a reference edge and/or reference-seam is determined by a first camera, in a leading direction of the application facility, in order to control and/or regulate the application facility according to the reference edge--by the recorded images of the first camera. Simultaneously and/or directly after applying the adhesive trail onto the substrate and/or the fold or location where components abut, a second camera carries out online monitoring of the applied adhesive trail in a trailing direction,--(i.e. the adhesive trail is applied onto the substrate

**SUBSTITUTE SPECIFICATION MARKED UP**

and then the second camera checks the quality of the adhesive trail that was just applied.). According to the invention, this control or regulation of the application facility according to the reference edge facilitates concurrent seam application guidance for two components to be glued together and online monitoring of adhesive application and/or sealing agent application. Thus is achieved, a reduction of the sealing agent applied, since is achieved, because the seam application guidance and simultaneous control necessitate the use of less material due to the compensation of tolerances.

[0010] Further advantageous developments are evident from the subclaims. Accordingly, for a three-dimensional positional correction with regard to positional tolerances of the individual components and/or tolerances of joining seams, it is advantageous for the reference contour and/or a feature to be determined by at least two cameras, in order to. The two cameras carry out a three-dimensional positional correction for the application facility by means of the stereometry procedure.

[0011] It is also advantageous if the two cameras record the substrate, a section of the component or one or more components in the form of a full image or a large image, whereby the full images or large images of the two cameras comprise an overlapping area in a leading direction, and whereby the. The three-dimensional recognition of reference contour position resulting results in the overlapping area is to be used for gross adjustment of the application facility prior to applying the structure.- In this context, corresponding correction values are transmitted to the application facility and/or the to a robot in order to shift its coordinatethe robot's coordinant system for the application of the adhesive agent.

[0012] If a projection is made onto the area of the reference contour for three-dimensional analysis, in particular (e.g., if one or more laser lines are applied onto the substrate in the form of a projection,) then a three-dimensional analysis of the profile with regard to the height and contour of arbitrary components can be facilitated even. Even though thisthe reference contour is not analyzable by common image processing without an additional projection.

## SUBSTITUTE SPECIFICATION MARKED UP

[0013] Moreover, it is particularly advantageous a particular advantage is if the reference contour is determined just by a first camera in a leading direction to regulate the progression of the structure to be applied according to the reference contour, and whereby the. The first camera records just a strip of the image for online regulation of the application of the adhesive structure.- By means of this partial scan and/or partial read-out of the image recording chip, only small data streams need to be processed such that the image recording rate can be increased several-fold.- In this context, the images are recorded at defined fixed time intervals and are independent of the speed of the application facility and/or the robot speed.

[0014] If the second camera uses just a strip of the image for online monitoring of the applied structure, the adhesive application can proceed at high a higher speed and the. The seam application guidance can proceed at high a higher speed in an online fashion, since because both cameras facilitate high-frequency image recording and rapid analysis with just one sensor with two cameras.- In this context, a reference edge is determined in a leading direction parallel to the online inspection of the track applied sealing agent track applied, and the difference. Difference values are transmitted to the robot for correction of the track such that the accuracy of the application of the sealing agent application can be increased significantly increased and a reduction of the material needsneeded is attained.- Due to this only partial read-out of the image recording chip of the individual cameras, images of all cameras can be captured synchronously, in parallel, and simultaneously.

[0015] According to an advantageous embodiment, the strips of the images of the cameras are recorded to form a single sequence of images and whereby the. The image recording rate is increased in line with the data reduction achieved by recording just a strip of the image in order to increase the speed of the automatic application and monitoring of the sealing agent application.- By storing a single sequence of images for all the cameras, the respective images of the individual cameras can be assigned according to the travel of the application facility as a function of location.

## SUBSTITUTE SPECIFICATION MARKED UP

[0016] If each camera uses only a part, in particular approx.-imately a third, fourth or fifth, of the picture lines as a strip of the image, the image recording rate is multiplied accordingly. ~~in~~ In particular, the image recording rate is multiplied essentially three-fold, four-fold or five-fold.

[0017] Moreover, it is advantageous for a parameterization and a recording of the application track to proceed in a single image recording run, whereby the images of all cameras are stored in a sequence of images.

[0018] According to the invention, the stored sequence of images ~~uses~~use the robot travel path-and/or, the robot travel time-or, the robot coordinates,coordinants as well as the position, the contrast, the gray scale value-or, color value, the width, and the quality of the applied structure for parameterization.

[0019] ~~Since~~Because only a small amount of data has to be included in the parameterization calculation and because of the high image recording rate, ~~it is feasible to record~~recording comparably short partial sections of the sealing agent application and of the reference contour and/or joining seam, ~~which are, for example (e.g.,~~ between 1 mm and 3 mm; in length-) is feasible. Moreover, it is advantageous to store the structure to be applied by parameterization essentially in the form of a vector chain, ~~whereby a.~~ A high image recording rate and short partial sections of essentially between 0.5mm and 4mm, in particular between 1 and 3mm, are used.- The vectorization is advantageous in that the adhesive trail in the form of a vector chain can be stored in a camera-transcending global coordinate system.\_ In contrast, traditionally, only a local camera image-oriented coordinate system is being used.- The invention thus facilitates that a switch of the sensor head only necessitates recalibration and/or new calibration without having to teach-in the adhesive trail again.

[0020] According to another advantageous embodiment, ~~itan~~an advantage is advantageous to use three cameras, whereby each camera is used and/or can be used both

## SUBSTITUTE SPECIFICATION MARKED UP

for regulation in leading direction according to the reference contour and for monitoring of the applied structure in a trailing direction, whereby the. The three cameras each comprise an overlapping area to the adjacent camera on a circular line. As a result, a sensor with three cameras can be attached to be fixed on the application facility, since each individual camera can assume both the regulation of seam application guidance and online monitoring of sealing agent application. Advantageously, the angle values of the circular line from 0° to 360° form a global coordinate system, whereby a. A segment of the circular line is assigned to the images of the individual cameras in order to carry out on thisthe circular line either the seam application guidance or the monitoring of the sealing agent. As a result, two of the three cameras are always active for analysis, i.e. one for seam application guidance and one other for the monitoring of sealing agent application.

[0021] Another advantage is that an automatic switch is made, when the reference contour or the adhesive trail progresses from one camera to the next camera, i.e. in that. For example, the activation is transferred from the one camera to the other camera when the application structure or the reference contour progresses from the segment of the circular line of the one camera via the overlapping area to the segment of the circular line of another camera.

[0022] Since the images are recorded very shortly one after the other (e.g., every 0.5 to 4, mm; in particular, 1 to 3 mm), it can be assumed that the position of the adhesive trail and/or joining edge cannot change too strongly, which significantly improves the significance and/or reliability of the a-priori knowledge such that it-the location of the track can be predicted-where the track will be located. One positive effect of this-such a priori knowledge is that the computer can recognize fully automatically the position of the track even in the absence of the expert knowledge of a human being, since the computer already knows approximately where the track will be progressing in the next image. This allows the search area to be reduced and the speed of analysis to be increased.

## SUBSTITUTE SPECIFICATION MARKED UP

[0023] According to the present invention is provided an apparatus is provided for automatic application and monitoring of a structure to be applied onto a substrate, preferably an adhesive line or adhesive trail, for carrying out the method according to the invention, whereby at At least one illumination module and one sensor unit are provided, and whereby the The sensor unit is made up of at least two cameras that are provided around an application facility for applying the structure to be applied onto the substrate and are arranged on thisthe application facility such that at least one camera is provided in a leading direction for regulation of the application facility by means of a reference contour and at least one camera is provided in a trailing direction for simultaneous online monitoring of the structure applied onto the substrate.— The apparatus, according to the invention, can therefore be used, for example, to guide a seam as a reference contour for the control of the application facility and/or robot control, and. The apparatus can simultaneously carry out an online control of sealing agent application, such that less material is used in sealing agent application since the width of the adhesive agent track can be reduced due to the guidance of the application facility.

[0024] If the optical axes of the individual cameras essentially intersect, in the direction of view, (e.g. the axial longitudinal axis of the application facility); or if the optical axes of the individual cameras are directed to be parallel to each other, and (e.g., in particular are directed to be perpendicular to the substrate, it is advantageous) an advantage according to a development of this type is that a narrow area around the application facility can be monitored at a suitable resolution and a high image recording rate.

[0025] According to a preferred embodiment, the individual cameras, in particular 3 cameras, are arranged at equal distances from each other in the direction of the circumference.

[0026] Advantageously, the individual cameras interact with each other such that the images of the cameras are stored in a sequence of images, whereby these images are composed by the software from the three partial sections of the individual cameras that

**SUBSTITUTE SPECIFICATION MARKED UP**

were recorded synchronously and captured in parallel.

[0027] If a projection facility projecting one or more features, in particular strips, onto the substrate for the three-dimensional analysis is provided on the application facility, arbitrary components can be used for correction and/or adjustment of the application facility prior to applying the structure.

[0028] According to a preferred embodiment, the projection facility emits one or more laser lines for a three-dimensional profile analysis.— Arranging at least two projection facilities around the application facility facilitates a gap-free three-dimensional analysis around the application facility, ~~whereby the~~. The analysis of sealing agent height and sealing agent contour, as well as position and width, can be carried out according to the principle of triangulation by means of image processing.

[0029] According to a development of an invention, the cameras are arranged around the application facility. The cameras are arranged such that at least an essentially circular edge scan (e.g., in particular in the form of a circular caliper;) is formed whose center is formed by the application facility of the structure.- In this context, one or more circular calipers can be used that facilitate the determination of the edge of the adhesive trail on a circular line.

[0030] According to a preferred embodiment, the individual cameras comprise an overlapping area of 30° to 900° each, in particular essentially 60°, relative to the next camera. This overlapping area facilitates fully automatic switching between neighboring cameras when the adhesive trail progresses from the monitoring area of one camera to the monitoring area of the next, since the camera. The selection of the camera is not bound to the robot position or to a time component, but rather always refers to the actual inspection results, i.e. is. For instance, the inspection results are based on the arrangement on the circular line of the circular caliper and/or the global coordinate system formed thereby.

## SUBSTITUTE SPECIFICATION MARKED UP

[0031] Moreover, it is advantageous for the illumination module to be made up of light emitting diodes (LEDs), in particular infrared LEDs, ultra-violet LEDs (UV LEDs) or red-green-blue LEDs (RGB LEDs).

[0034] Moreover, ~~it is of one~~ advantage is to use a calibrating disc with individual form elements for calibrating the individual cameras for the assignment of the angle assignment, ~~whereby~~. The said form elements comprise, in particular, an angle distance of essentially 10°.- This allows for assignment of the scaling factor, angle assignment, and center, as well as radius of the search circle for the individual cameras.- According to the invention, the calibrating disc comprises at least three marker sites that are arranged in a circular arc of the calibrating disc of essentially 0°, 120°, and 240°, in order to calibrate three cameras.

[0032] ~~Further advantageous developments of the invention are the subject of the remaining subclaims.~~

[0033] Advantageous developments of the invention shall be illustrated in an exemplary fashion by means of the following drawings.

[0034] Figure 1 shows a schematic side view of an apparatus according to the invention for application and monitoring of an adhesive trail.

[0035] Figure 2 shows a perspective view of the apparatus according to the invention of ~~figure~~Figure 1.

[0036] Figure 3 shows the travel path of the apparatus according to the invention for application and monitoring of an adhesive trail.

[0037] Figure 4 shows another travel path of the apparatus according to the invention with regard to the switching of the relevant camera.

[0038] Figure 5 is a view of a single image composed from three image strips

## SUBSTITUTE SPECIFICATION MARKED UP

from three cameras for seam application guidance and online monitoring of sealing agent application at one edge of a component.

[0039] Figure 6 is another view of a single image composed from three image strips from three cameras, whereby two overlapping components are being glued together.

[0040] Figure 7 shows a schematic view of a calibrating device according to the invention for calibrating the individual cameras of the apparatus according to the invention for automatic application and monitoring of a structure to be applied onto a substrate.

[0041] Figure 8 shows a top view with regard to the basic principle of seam tracing.

[0042] Figure 9 shows a top view with regard to the principle of 3D positional recognition.

[0043] Figure 10 shows a top view with regard to profile analysis.

[0044] Figure 11 is a schematic side view of the apparatus according to the invention with projection facility.

[0045] Figure 12 is a schematic top view of a projection applied to be circular.

[0046] In the following, the design of the apparatus according to the invention for recognizing a structure to be applied onto a substrate is illustrated according to figuresFigures 1 and 2.

[0047] Reference number 10 indicates the schematically shown apparatus in  
Figure 1 for application and monitoring of an adhesive trail.– In the center of the

## SUBSTITUTE SPECIFICATION MARKED UP

apparatus, according to the invention, is arranged an application facility 11 by means of which an adhesive trail 20 is applied onto a substrate and/30 or onto a sheet of metal 30 31 proceeding from right to left in fig.Figure 1.- Three cameras 12, 13, 14 are arranged at equal distances from each other in a circle around the application facility 11, each of which. Each camera is directed at the application facility 11.- As is evident from figure Figure 1, the axial longitudinal axes of the three cameras 12, 13, 14 intersect the axial longitudinal axis of the application facility 11 just below the substrate 30 such that. Thus, the focus of the individual cameras is arranged right around the area of the application facility 11, in particular, on a circular line.

[0048] In the inspection of the adhesive, either the application facility 11 with the cameras or the substrate 30 is moved, whereby the. The adhesive trail 20 is simultaneously applied to the substrate 30 by means of the application facility 11, and whereby while the cameras 12, 13, and 14 monitor the applied structure. For this the purpose, it is feasible to move of inspecting the adhesive, either the application facility 11 with the cameras or the substrate 30 is moved in order to apply the adhesive trail trail 20 onto the substrate 30 such as to follow a desired progression.- In the method according to the invention, a first camera then determines a reference contour and/or, a reference line, or reference edge in a leading direction, as shown by camera 14 towards the left in the case shown, in Figure 1. In order to regulate the progression of the structure to be applied, according to the reference contour, whereby the the images recorded by the first camera 14 are used to guide the application facility 11 in the application of the adhesive trail. 20. The adhesive trail 20 is applied by the application facility 11 simultaneous to the determination of the reference contour, whereby the. The application facility 11 is moved to the corresponding track and/or the corresponding adhesive trail progression according to the correction values determined by the first camera. 14. Synchronous to this process, the adhesive application track is monitored by a second camera in a trailing direction.- By this means, the cameras that are being moved along can control the adhesive trail 20, while it the adhesive trail 20 is being applied, according to the reference contour independent of the travel pathand. The cameras monitor the quality of the adhesive trail 20 online.- In fig.Figure 2, the adhesive trail 20 progresses from left to

## SUBSTITUTE SPECIFICATION MARKED UP

right which is shown as a continuous line.- The desired progression of the adhesive trail 20 that can be applied to the metal sheet 31 and/or substrate 30 as reference contour (for example by laser or be embossed) is shown to the right of the application facility 11 by means of a dashed line.

[0049] Figure 3 then shows~~illustrates~~ the progression of the adhesive trail 20 as indicated by arrows 21 and 22, whereby the direction and/or field of view of the three individual cameras is shown in three sites. The field of view 23, 24, and 25 of the three individual cameras each12, 13, and 14 is shown in three sites. The field of view 23, 24 and 25 of the three individual cameras 12, 13, and 14 are indicated by a rectangle drawn with a continuous line 23, a rectangle drawn with widely dashed lines 24, and a rectangle drawn with narrow dashed lines 25. As is evident from figureFigure 3, the direction of the individual fields of view 23, 24 and 25 of the cameras remains constant at all times whereby and only the whole apparatus is moved.

[0050] Figure 4 shows~~illustrates~~ another progression of an adhesive trail 20, whereby it is indicated in each case, that illustrates which field of view 23, 24 and 25 is active, i.e. (e.g., marked at “active”). For example, Figure 4 depicts which camera having has the corresponding field of view shown as a rectangle is 27 (e.g. marked as “active”) while traveling along the adhesive trail 20 for quality control purposes.- Moreover, at least a second camera is active in a leading direction for seam application guidance and/or the progression of the sealing agent track, though this is (not shown here for reasons of clarity of presentation). However, it is evident that the cameras indicated to be active are arranged in a trailing direction and are switched automatically according to the progression of the adhesive trail 20. Therefore, at least one camera is active at any time for seam application guidance and fine adjustment of the application facility according to the given reference contour in the leading direction, which is opposite to the trailing direction.

[0051] Figure 5 then shows~~illustrates~~ three image strips which that each represent a relevant section and/or strip of an image of the three individual cameras 12, 13, and 14

## SUBSTITUTE SPECIFICATION MARKED UP

of ~~figure~~Figure 1.- According to the method of the invention, each camera 12, 13, and 14 records just a strip of the image 32, 33, and 34 in order to reduce the amount of data accordingly such that the recording rate can be increased.- These individual image strips 32, 33 and 34 of the three cameras 12, 13, and 14 are then joined into an image, whereby the image recording occurs at defined fixed time intervals and independent of the robot control of the application facility.- For example, the cameras 12, 13, and 14 only record a strip of the image, ~~whereby instead~~32, 33 and 34. Instead of an image height of 480 pixels, an image height of approx.~~imately~~ 100 pixels (100 image lines) is used.- By means of this partial scanning technique, i.e. (e.g. partial reading-out of the image recording chip), only small data streams are generated such that. Thus, the image recording rate can be increased several-fold accordingly. Synchronous image recording and parallel image capture allow the three image strips 32, 33 and 34, one below the other, to be composed into a single image.- As a result, the three ~~images~~, i.e. the ~~three~~ image strips, 32, 33, and 34 are correctly arranged and assigned with regard to location and time relative to the travel path of the application facility 11 and without further ~~add~~~~delay~~ and can be processed accordingly. ~~This specific~~. Thus, the image recording technique therefore facilitates simultaneous and parallel recording of individual camera images, which achieves an increase in~~increases~~ the image recording rate for both for guidance and/or regulation of the application facility 11 and for online monitoring of the adhesive agent applied, whereby the images of all cameras 12, 13, and 14 are stored in a sequence of images.

[0052] Once the images of the three cameras 12, 13, and 14 are stored in a sequence of images, a parameterization of ~~this-a~~a reference track is carried out as the subsequent step of teaching-in the reference adhesive trail.- The robot travel path, robot travel time, direction, width, and quality of the adhesive trail 20 are used in the parameterization. ~~This~~ The parameterization results in a type of vector chain for the adhesive ~~frail~~ which allows to attain the trail 20. The vector chain attains high image recording ~~rate~~rates and comparably short partial sections (e.g., between 1 and 3mm). Vectorization has another advantage in that the adhesive trail 20, being in the form of a vector chain, can be stored in a camera-transcending global coordinate system.

## SUBSTITUTE SPECIFICATION MARKED UP

[0053] As is evident from ~~figure~~Figure 5, which shows a ~~illustrates~~ seam application guidance at an edge of a component, the seam inspection is carried out online in the middle strip of ~~figure~~Figure 5, whereby the segment of a circle is the area, in which the first camera provides for monitoring of the adhesive.

[0054] Application facilities and/or robots work with an internal interpolation clock time of 12 ms, for example. The regulation of seam application guidance according to the lower strip of ~~fig.~~Figure 5 cannot occur more rapidly than this interpolation clock time. At ~~Therefore,~~ at a maximal robot travel speed of 700 mm/s, ~~this means only that~~ the path traveled in 12 ms is 8.4 mm. Accordingly, if a correction value is determined at time point x, the correction can be made only at the next interpolation clock time, (i.e. 8.4 mm after determination of the value). As a result, the reference edge must be captured at least 8.4 mm ahead of the nozzle. This area is covered by the arrangement of the optical sensor system and correction values are made available in due time by the rapid analytical cycle (e.g., < 5 ms). ~~Since the cameras~~ Because the cameras 12, 13, and 14 are attached around the application facility such as to be ~~11~~ in a fixed in-position, the progression of the adhesive trail 20 changes, whereby. Thus, the seam correction can therefore be carried out in the first strip according to the first camera, in the second strip according to the second camera or in the third strip according to the third camera. Consequently, as described above with regard to the online monitoring of adhesive application, another camera becomes active for seam correction when the reference seam migrates from the field of view of one camera into the field of view of another camera.

[0055] The bottom strip of ~~fig.~~Figure 5 shows a bright cross on the line perpendicular to the edge of the component right at the edge of the component that is used as reference edge for seam application guidance. Paralleling this, the seam inspection for monitoring of sealing agent application is carried out in an online fashion in the middle strip 33 of ~~fig.~~Figure 5.

[0056] If the adhesive trail 20 progresses out of the field of view of a camera, the

## SUBSTITUTE SPECIFICATION MARKED UP

adhesive trail 20 is transiently in the overlapping area of the ranges of angles of the two cameras. If the adhesive trail 20 then progresses from the segment of the circular line of the one camera via the overlapping area to the segment of the circular line of another camera, an automatic switch is made from the one camera to the other camera. This is shown, in particular, in figureFigure 4 by means of the active fields of view 27 of the individual cameras.

[0057] The advantages mentioned above are attained by the individual cameras forming a circular caliper whose center is formed by the application facility 11, whereby the search for both the reference edge and the edges of the adhesive trail 20 proceeds on a circular line directly around the application facility 11. For this purpose, it is essential that the individual cameras 12, 13, and 14 are directed at the application facility 11, whereby the axial longitudinal axes of the individual cameras 12, 13 and 14 intersect the longitudinal axis of the application facility 11.

[0058] The illumination module (not shown here) for the apparatus according to the invention is made up of light emitting diodes (LEDs), in particular infrared LEDs, ultraviolet LEDs (UV LEDs) or red-green-blue LEDs (RGB LEDs). In order to attain as little movement or blur as possible and/or have a high contrast in image recording, the LEDs can be flashed, i.e., For example, short, strong pulses of current on the order of 1.0 to 0.01 ms can be applied to the diodes. In this context, light-emitting diodes capable of emitting light of various colors are particularly advantageous such that because the sensor design can be switched to other types of adhesive and/or adhesives or other colors of adhesives without reconfiguration.

[0059] A teach-in run and/or a teach-in of a reference adhesive trail is illustrated in the following paragraphs below.

[0060] The teach-in process of the reference adhesive trail can be started by the user by marking the position of the adhesive trail: 20. This is sufficient for fully automatic recognition of a position and a direction of the adhesive trail 20 in the

## SUBSTITUTE SPECIFICATION MARKED UP

subsequent camera images, ~~since because~~ the image recording rate is sufficiently high and the individual images are recorded very shortly after one another, ~~for example (e.g., every 1 mm to 3 mm:).~~ From the starting point, the adhesive is scanned image by image, ~~whereby the~~. The adhesive trail position and the adhesive trail angle detected in the current image are used for the upcoming image as *a priori* knowledge. ~~This~~ The a priori knowledge facilitates fully automatic capture of the adhesive trail 20 without a human being having to determine and/or assess the image and/or the position of the adhesive trail. 20. As a result, the search area can be limited and/or adjusted.

[0061] Figure 6 shows~~illustrates~~ a guidance of a seam application in the overlapping area of two components, ~~in particular particularly~~ at a place ~~at which where~~ the two components abut.- The second camera shows the strip of the second camera read-out according to ~~the~~ a partial scanning method, in which the position of the overlap of the two metal sheets is determined as a reference contour and/or a reference edge to guide the seam application.- The strip of the third camera, in which the applied sealing agent track is monitored in parallel to seam application guidance, is shown in the bottom strip of fig.Figure 6.- For this purpose, the segment of a circle is shown in the bottom strip, in the middle of which progresses the adhesive trail 20 as indicated by a circle.- The image recording strip of the first camera 14 is shown in the top strip of fig.Figure 6.

[0062] Figure 7 shows~~illustrates~~ a calibration facility 40 in the form of a circular calibrating disc ~~in order to assign~~. The calibration facility 40 assigns to the individual cameras ~~their~~ 12, 13 and 14 a scaling factor, ~~their~~ an angle assignment, and the center as well as ~~the~~ and radius of the search circle.- The calibrating disc consists of individual form elements ~~and/or~~, shown as dots 41, that are arranged on a circular line ~~and~~. The form elements are spaced at an angle distance of essentially  $10^{\circ}$  from one another. Moreover, marker sites 42 are arranged at equal distance from each other in order to calibrate the three cameras: 12, 13, and 14. A compensation calculation is ~~used to calculate from the coordinates~~ determined by utilizing the coordinants of the centers of the individual dots, ~~on the one hand~~, the scaling factors of the individual cameras 12, 13 and, ~~on the other h~~ 14 and, the center as well as and radius of the search area.- The marker

**SUBSTITUTE SPECIFICATION MARKED UP**

sites are located at angles of  $0^\circ$ ,  $120^\circ$ ,  $240^\circ$  in the global coordinate system allowing the angle assignment and the corresponding fields of view of the individual cameras 12, 13, and 14 to be determined.- The field of view of for the individual cameras is12, 13, and 14 are indicated,in particular, by the three rectangles 43, 44, and 45 shown in figureFigure 7,whereby the. The form elements 41 can correspond to the circular line of the circular caliper for detection of the adhesive trail 20.

[0063] Figure 8 showsillustrates three strips around the application facility 11 each by dashed lines that represent the read-out area for the partial scan of the individual cameras: 12, 13, and 14. The strip 31 of the first camera determines the reference edge 35 in order to control and/or regulatethat controls and/or regulates the application facility 11 according to the progression of the reference edge.- Image strip 31 is therefore facing in a leading direction and measures the position of the reference edge and/or fold 35 such that the application facility 11 applies the sealing agent onto the track correctedcorrectly according to the reference contour 35.- After correction of thea robot track with regard to thea coachwork position, the joining seam is recognized by driving to thea first position and activating thea seam application guidance.- After release of the process (e.g., a seam is recognized), the robot track continuously receives correction values that are perpendicular to the application direction taught-in.- In this context, thea capture area can be  $\pm 15\text{mm}$ -and, whereby thea regulation area is  $< \pm 1 \text{ mm}$ .- The communication between the image processing system and the robot system and/or application facility proceeds, for example, by means of a standardized Ethernet interface using an XML protocol.\_ In the trailing direction, the two image strips 32 and 33 are shownthat intersect in the area of the sealing agent track 2021.

[0064] The online monitoring of an applied adhesive trail shall be illustrated briefly in the following:paragraphs. The application facility 11 shown in figureFigure 1 applies the adhesive frailtrail 20 onto the metal sheet 30,whereby the 31. The application facility 11 is moved jointly with the cameras 12, 13, and 14 over the metal sheet 3031 and regulated according to the reference contour.\_ However, a kinematic inversion is also feasible, i.e.for example, the metal sheet 3031 being moved and the

## SUBSTITUTE SPECIFICATION MARKED UP

application facility 11 with the cameras 12, 13, and 14 being arranged to be fixed in position.- The applied adhesive trail 20 is determined and analyzed synchronously and in parallel by one of the cameras 12, 13, 14 on the circular line of the circular caliper illustrated according to figure(shown in Figure 5, whereby each). Each camera 12, 13, and 14 records only a strip of the image 32, 33, and 34 and joins these into a single image.- The image recording rate is increased in accordance with the data reduction attained bybecause each camera recording12, 13, and 14 records only a strip of the image, whereby the 32, 33, and 34. The individual image strips 32, 33, 34 in the joint image facilitate the synchronous-and, parallel, as well as simultaneous capture of the three camera images, and whereby the. The individual images of the three cameras 12, 13, and 14 can be assigned directly as a function of location.- As a result, seam application guidance and online monitoring of the adhesive trail 20 in real-time is feasible that and achieves high accuracy at high travel speeds due tobecause of the high image recording rate both in the regulation according to the reference edge and in the inspection of the applied adhesive trail 20.

[0065] Fig:ure 9 showsillustrates the basic principle of 3D positional recognition which that is carried out prior to applying a sealing agent. Since Because the metal sheets 31, for example raw coachwork of vehicles, are not always positioned in exactly the same position by the supply-supplier of the technology and the position of the joining seams is associated with tolerances, gross adjustment and/or gross positioning of the apparatus according to the invention is advantageousan advantage. For this purpose, the camera image fields are switched to a large image-and/or, a standard size, or a full image, which is indicated for each particular case by the dashed line(s) 51 and/or 52.- The standard camera image field 51 shows the expanded field of view of a camera reading-out just the corresponding strip 31 according to the partial scanning procedure.- The strip 32 is scaled down analogous to this and accordingstrip 52 and according to the ratio to-of the standard camera image field 52.- For example, the image strip 31 and/or 32 is scaled down by a suitable software-to, for example, to half its-the width and 1/5 of its-the height-of the image fields 51 and 52. For reasons of clarity of presentation, the corresponding standard camera image field 53 with corresponding image strip 33 is not shown here.. In

**SUBSTITUTE SPECIFICATION MARKED UP**

the 3D positional recognition, an arbitrary feature 60 within the overlapping field of view of the two camera image fields 51 and 52 is measured.- Since the two camera image fields 51 and 52 overlap in the area of feature 60, the procedure of stereometry can be used ~~in order~~ to facilitate a three-dimensional analysis, for example, of a hole or an edge of the component.- If, for example, a seam of two components has been recognized, the application facility 11 can carry out an automatic correction of position through the help of the sensory system in order to carry out the correction of the robot track and/or application facility track in an online fashion, as described in fig.Figure 8.- The same sensory system can carry out at the same time the quality control of seam sealing in an online fashion, as ~~is also described in fig.~~Figure 8. ~~This~~ The 3D positional recognition provides for positional correction of the application facilityfacility11 and online regulation of the progression track of the application facility 11 as well as online monitoring of sealing agent application with a single sensory system that is ~~made up~~configured, for example, ~~of~~with three cameras 12, 13 and 14 in a fixed position arranged around the application facility ~~such as to be fixed in position.~~11. In this context, just a strip of the image 31, 32, 33 is recorded according to the invention in order to utilize small data streams to achieve an increase in the image recording rate.- The use of the partial scanning technique thus provides for an image refresh rate of approx.imately 240 Hz or ~~lower, less~~. The images are therefore recorded at defined fixed time intervals and are independent of the speed of the robot and/or the application facility 11. In addition, a frame grabber board (=e.g., a personal computer (PC) board for capturing images from the camera) is used in the analytical PC allowing images from all three cameras 12, 13, and 14 to be captured synchronously and in parallel.- The images are subsequently composed into one image (i.e., 3 strips one below the other) providing the advantage of three images each being directly assigned accordingly in a location-dependent fashion.

[0066] Moreover, it is sufficient, in particular, to search for and analyze, for example, the sealing agent track in one of the three images. If the angle value exceeds a certain value, an automatic switch to the neighboring camera is made.- In this context, the angle value refers to a full circle of 360°, which results in a global coordinate system.

**SUBSTITUTE SPECIFICATION MARKED UP**

Each camera comprises an area of overlap with the next camera.- The selection of the camera is made independent of the position of the application facility ~~and/or 11~~, robot position, ~~and/or independent of~~ a time component, but rather always refers to the actual inspection results which are captured in the global coordinate system.- This prevents errors that are generated by the relative inaccurate robot controls ~~and/or~~ application facility~~facility 11~~ controls.

[0067] The three-dimensional profile analysis by means of a projection is described according to ~~figures~~Figures 10 and 11, ~~in order to provide for a positional correction of the application facility as described above according to figure 9. For reasons of clarity of presentation, fig.~~ Figure 10 again shows only illustrates by dashed lines two camera fields of view 51, 52 ~~indicated by dashed lines.~~ In the overlapping area of the two camera fields of view 51, 52 are shown a plurality of laser lines 60 that are used for a profile analysis with regard to the width and contour of structure lines and for generation of so-called soft contours.- The laser lines 60 are generated by a projection facility that can, for example, be arranged on the optical sensor with three cameras.- Moreover, the projection facility can just as well be arranged directly on the application facility 11.- The sensor with the three cameras is shown schematically by the circle 70.- The laser lines ~~and/~~60 or laser strips ~~are~~ projected onto the component ~~30~~ and ~~/~~32 or metal sheet ~~30~~ ~~highlight~~31 ~~highlighting~~ contours on the component ~~30~~ that cannot be used for a three-dimensional analysis by conventional image processing.- Artificial features are generated by means of the laser lines 60 on the component 32 and can subsequently be analyzed by means of image processing according to stereometry.- Thus, ~~figure~~Figure 10 shows the principle of three-dimensional positional recognition prior to the application of the sealing agent in case no hard, analyzable features are present.- In contrast, a hard contour is described by means of feature ~~60~~ ~~in fig.~~9 ~~as mentioned as illustrated by Figure 9 and as described above.~~

[0068] ~~Fig.~~ure 11 ~~shows~~illustrates a side view of the application facility 11 with a sensor unit ~~70 attached to it, whereby the~~71. ~~The sensor~~ ~~70~~unit 71, aside from the three cameras, can comprise at least two projection facilities 61 that project laser lines onto the metal sheet ~~and/~~31 or the substrate ~~30~~, as is shown schematically by the dashed line 62.

**SUBSTITUTE SPECIFICATION MARKED UP**

Arranging multiple projection facilities 61 around the application facility 11 allows a gap-free contour to be generated on the metal sheet 30, whereby the 31. The gap-free contour can be used for three-dimensional analysis sincebecause the sensor 71 and the projection facility 61 are calibrated.- Accordingly, fig.Figure 11 shows two projection facilities 61 in an exemplary fashion.- Projection facilities 61 of this type can, for example, project a laser onto the substrate and/or the component or can be made up of. In addition, projection facilities 61 can have an LED module comprising an adapter lens to generate a line on the substrate.

[0069] The projection facilities 61 can be used both for three-dimensional positional correction prior to sealing agent application as well as for online analysis of a height and a profile of the applied sealing agent.- For three-dimensional positional correction, the projection facilities 61 can, preferably, project multiple lines.- For height analysis, one or more projection facilities 61 should be provided that project a line or, as shown in fig.Figure 12, a circular contour onto the component and/or substrate. In this context, multiple Multiple lines can be advantageous for the analysis.

[0070] As shown in fig. 12, it is also feasible Figure 12 illustrates to determine sealing agent height and/or sealing agent contour and sealing agent position according to the principle of triangulation by means of the image processing simultaneously and directly after sealing agent application. For this purpose, a A round contour 63, for example, is applied to the metal sheet 3031 by the projection facilities, whereby the. The sealing agent and/20 or the sealing agent track 2021 provides for a change of height and position of the projected contour 63.- The round projection contour 63 thus changed in turn is determined by the individual object fields of the individual cameras. The 12, 13 and 14. Thus, the original shape of the projected contour 63 is thus deformed by the sealing agent 20 such that the width, contour, but also the height and position of the applied sealing agent 20 can be determined according to the principle of triangulation.- In the principle of triangulation, there is a defined angle between the camera and the projection facility 61, whereby the camera and the projection facility facility 61 are calibrated with respect to each other.- Because of the angle, the substrate contours

**SUBSTITUTE SPECIFICATION MARKED UP**

illuminated by the projection facility appear in different positions on the light-sensitive chip and/or charge-coupled device (CCD) chip or complementary metal oxide semiconductor (CMOS) chip as a function of their height such that the height and contour of the sealing agent can be calculated due to the calibration of the camera and projection facility 61.

[0071] According to an embodiment that is not shown here, the sensor 71 that is ~~made up, in particular, of~~ configured with three cameras 12, 13, and 14 arranged around the application facility ~~is made up~~ 11, which is configured such that the optical axes of the individual cameras 12, 13, and 14 are directed ~~such as to be~~ parallel to each other; ~~whereby the.~~ The cameras 12, 13, and 14 are, ~~in particular,~~ directed ~~such as to be~~ perpendicular to the substrate ~~and~~ 30 or metal sheet 31. An arrangement of this type allows the sensor 71 to be arranged particularly close to the area of sealing agent application, whereby the fields of view of the individual cameras 12, 13, and 14 comprise an overlapping area whose size depends on their wide angle.

SUBSTITUTE SPECIFICATION MARKED UP

METHOD AND APPARATUS  
FOR AUTOMATIC APPLICATION AND  
MONITORING OF A STRUCTURE TO BE  
APPLIED ONTO A SUBSTRATE

ABSTRACT OF THE DISCLOSURE

A method and apparatus are provided for automatic application and monitoring of a structure to be applied onto substrate. A plurality of cameras positioned around an application facility are utilized to monitor the automatic application of a structure on a substrate by means of a stereometry procedure. Three-dimensional recognition of a reference contour position results in the overlapping area to be used for gross adjustment of the application facility prior to applying the structure.